Space Weather Issues and Tools
Steve Johnson, NASA Space Radiation Analysis Group

Invited to serve as a panelist regarding Space Weather Operations and Spaceflight.

In addition, I was also asked to present a short presentation regarding SRAG operational tools and space weather as it could apply to commercial space transportation. This presentation will include basic environmental information regarding solar energetic particle events and some discussion slides regarding the operational impacts application as it may apply to commercial spaceflight.

No abstract was requested or provided.

Space Radiation Environmental Considerations for Commercial Space Flight

Steve Johnson, Neal Zapp

Space Radiation Analysis Group

Johnson Space Center

Space Weather Issues and Tools

10th Annual Commercial Space Transportation Conference

Who are we?

Space Radiation Analysis Group (SRAG)
Johnson Space Center

- Monitor, Assess and Inform Mission Control of Radiation Environment Conditions.
  - Support mission control:
    - 4 Hours/day under normal conditions
    - During the course of all EVAs
    - Continuous support during Solar Energetic Particle SEP events
- Conduct radiation measurements on Crew (Dosimetry) and on Spacecraft
- Operational Advocates for Radiation Health of Astronauts

How do we Protect the Crew from SEPs

The major real-time operational concern are Solar Energetic Particle events

Close Support with NOAA Space Environment Center

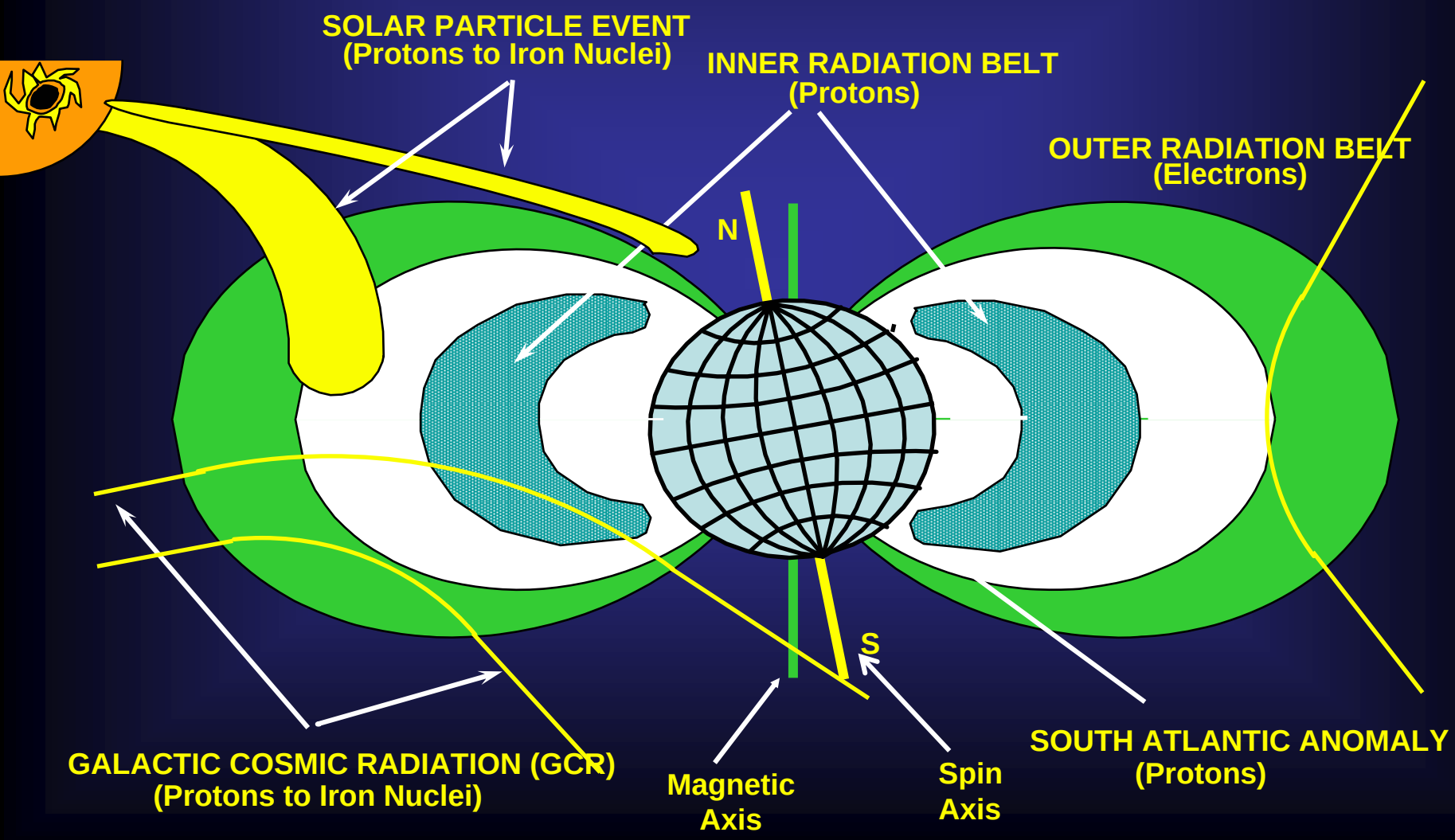
- Daily Status and Weather Reports
- Monitor real-time data feed from Radiation Detecting Satellites (GOES, ACE, SOHO)
- Data From Ground Stations

Mission Control activity

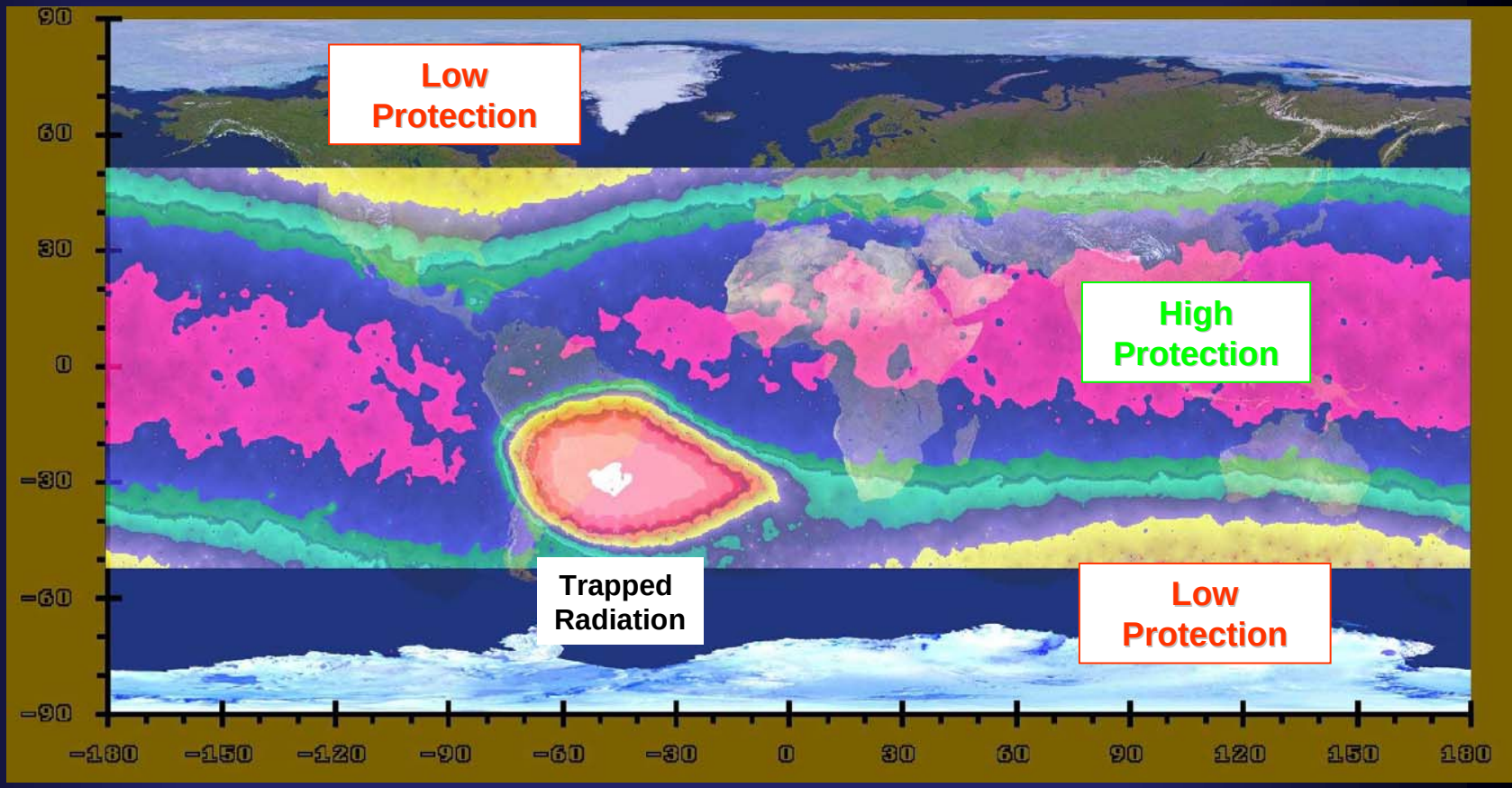
- Interpret Current Conditions and Trends as Applied to Current Mission
- Execute Computer models:
  - Using real-time NOAA GOES Satellite data
  - Models of the Earth's Protective Magnetic Field
  - Compare SEP Model Output against Spacecraft Measurements
- Advise Flight Management
  - Crew Shielding Recommendations to Flight Surgeon
  - Identify When radiation sensitive hardware will be at risk

Physics 101

THE MAGNETIC FIELD IS LIKE AN UMBRELLA PROVIDING SIGNIFICANT PROTECTION AGAINST SPACE RADIATION

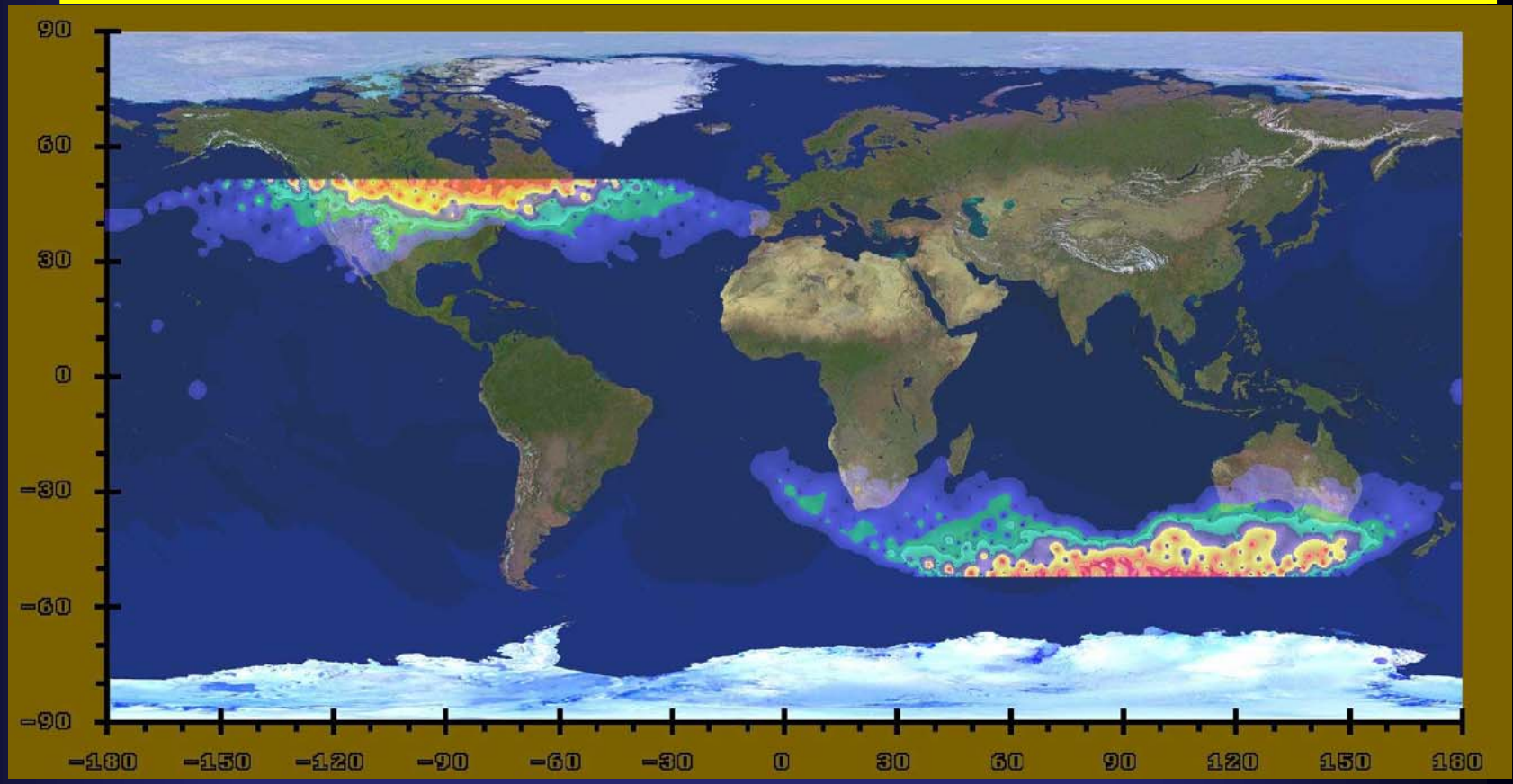


Space Radiation Environment – Where are we protected?



Dose Intensity and Ground Track Location
Least Protected Zones are within the yellow areas
– this is where SEPs will pose greatest risk

Space Radiation Environment – Where are we NOT protected?

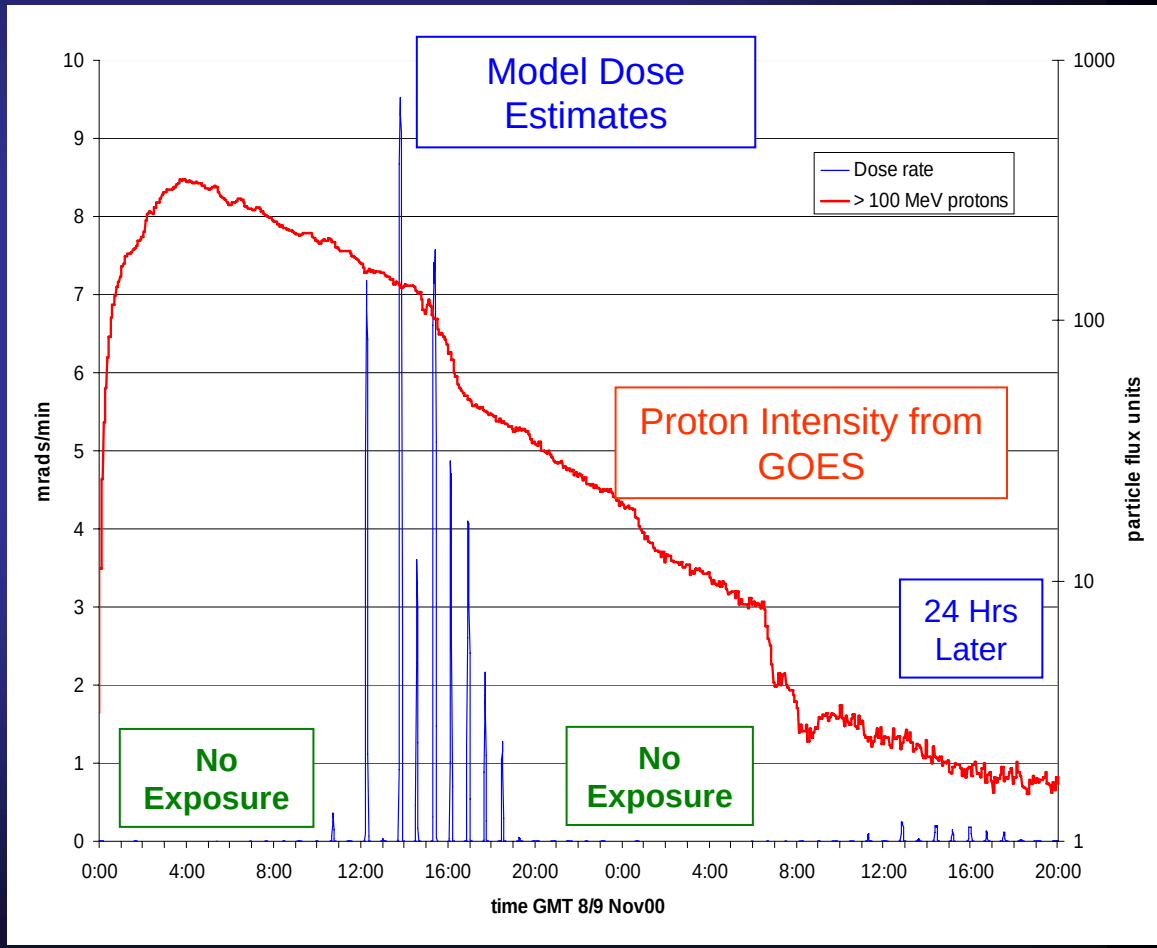


Dose Intensity and Ground Track Location During A Proton Event
A Difference Plot Subtracting a Normal Day from Proton Event Day
Note: SEPs location corresponds to the 'Yellow' regions on the previous plot

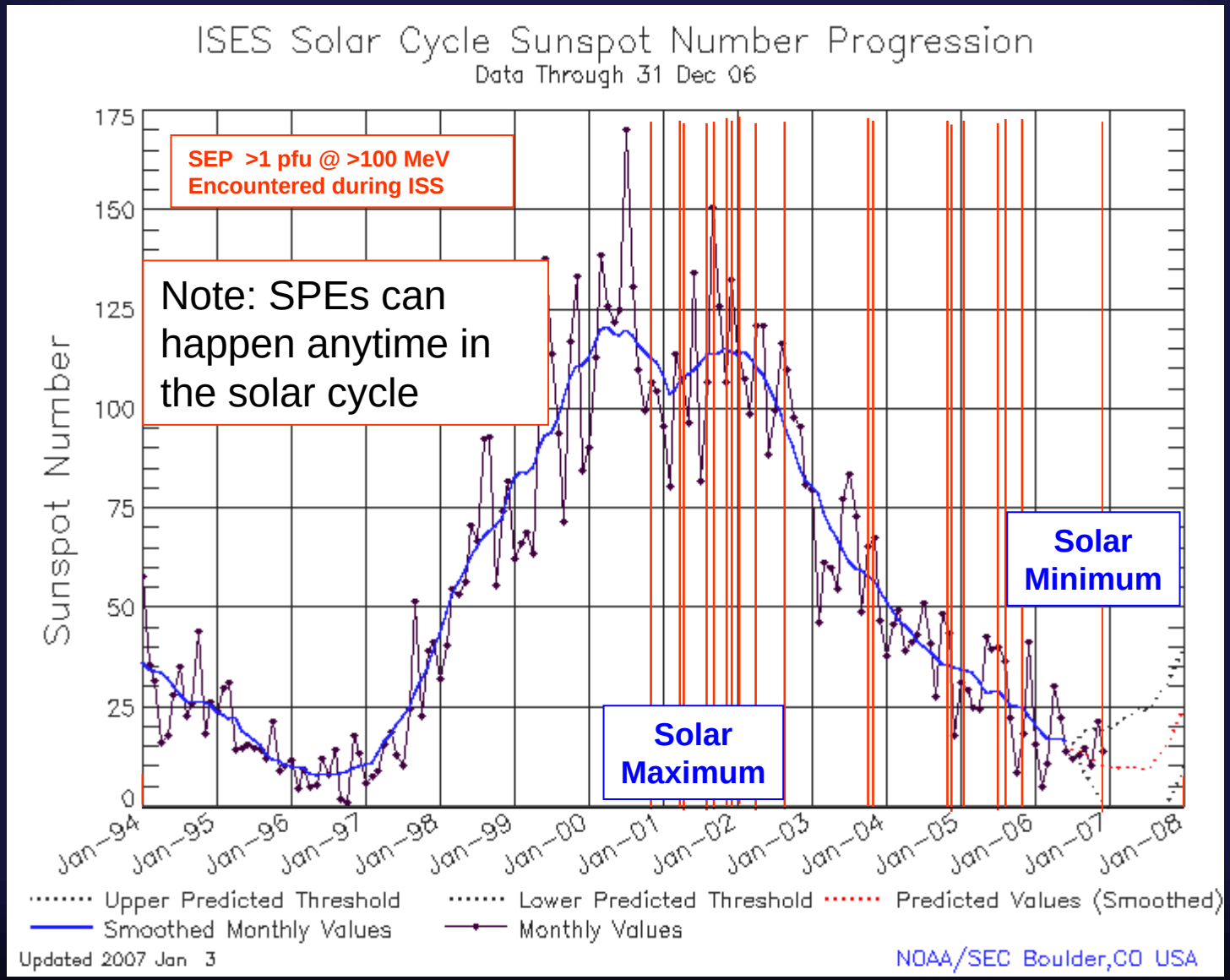
How would the radiation levels in orbit change during an event?

SEP Events as Observed at ISS (Low Earth Orbit)

- Characterized by short high-dose passes.
  - Peaks will be 45 – 90 minutes apart:
  - Timing is Trajectory dependent
- Passes correspond to trajectories in zones of low magnetic protection
- Usually bunched into 8-9 hour interval each day.
- Southern regions larger Northern regions



When do these Events happen?



Can We Forecast SEPs?

Well, no not at this time. Current State of the Art is Limited to Nowcasting. However ….

We recognize many parameters that are indicative of the "right" conditions. Some major ones are:

- **Active Region magnetic complexity and size**
- **Recent Activity**
- **Region Location**

It doesn't happen all at once. Generally

- **First indicator: Large X-ray flare**
- **If magnetically connected to the Flare region,**
  - **arrival times generally 15 – 30 minutes for well connected events**
- **An Hour or Longer To Reach Maximum for Major events.**

January 2005 was significantly outside the 'typical' profiles and much faster arrival and peak times! Exceptions will occur.

Considerable research into developing the capability to forecast an event

An Active Region is a group of sunspots magnetically intertwined.

So From a Practical Viewpoint, Where Are the Risks?

Flight profile	Inclination	Duration	Risk Level
Suborbital	Latitude < 40° N/S	Few minutes	Negligible: Exposure Unlikely
	Latitude > 40° N/S	Few minutes	Negligible: Slight Exposure possible
Orbital	Latitude < 40° N/S	Few Orbits (hours)	Negligible Extremely small
	Latitude > 40° N/S	Few Orbits (hours)	Minor: Trajectory Dependent
Orbiting/Station	Latitude < 40° N/S	Days	Negligible: Small
	Latitude > 40° N/S	Days	High Risk: Risk rises as inclination rises
Moon or Mars	Doesn't matter	Weeks/Months	Extreme

Note: Trapped Radiation needs to be considered for Longer duration orbital periods

So From a Practical Viewpoint, What Now?

Although the true risks and exposures may be low, it will be in your best interest to protect the Transportation Operators and Passengers

- Develop a plan to address Space Weather issues
- Compliance With Radiation Monitoring Regulations May Be Required
- Avoidance of SEPs Always The Best
  - Suborbital and short orbital flights should be able to avoid SEPs
    - A suborbital flight could be undertaken when “clear” and be completed before an event starts and achieves significant levels.
    - Short Orbital flights, may avoid low protection zones depending on trajectory

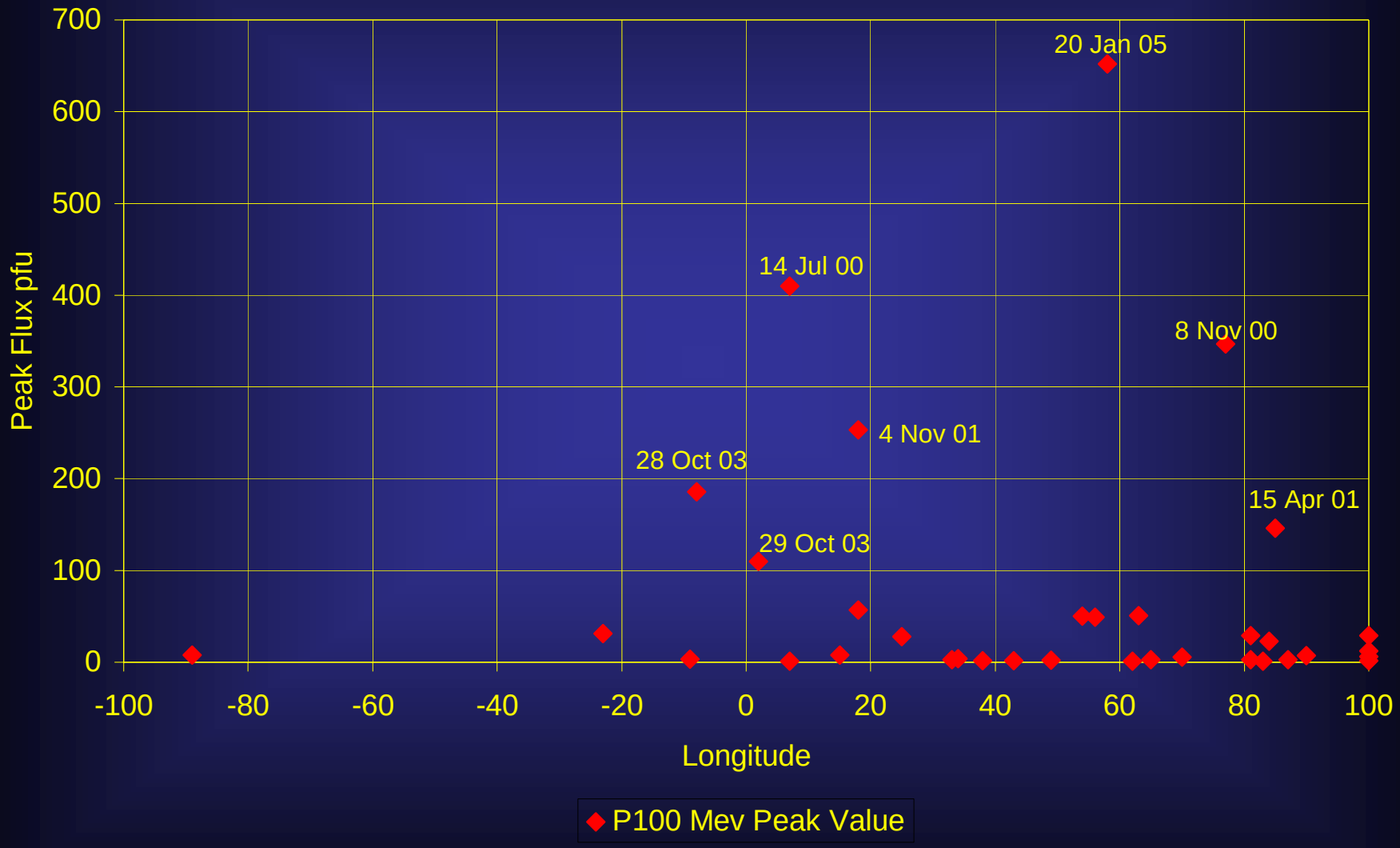
And ….

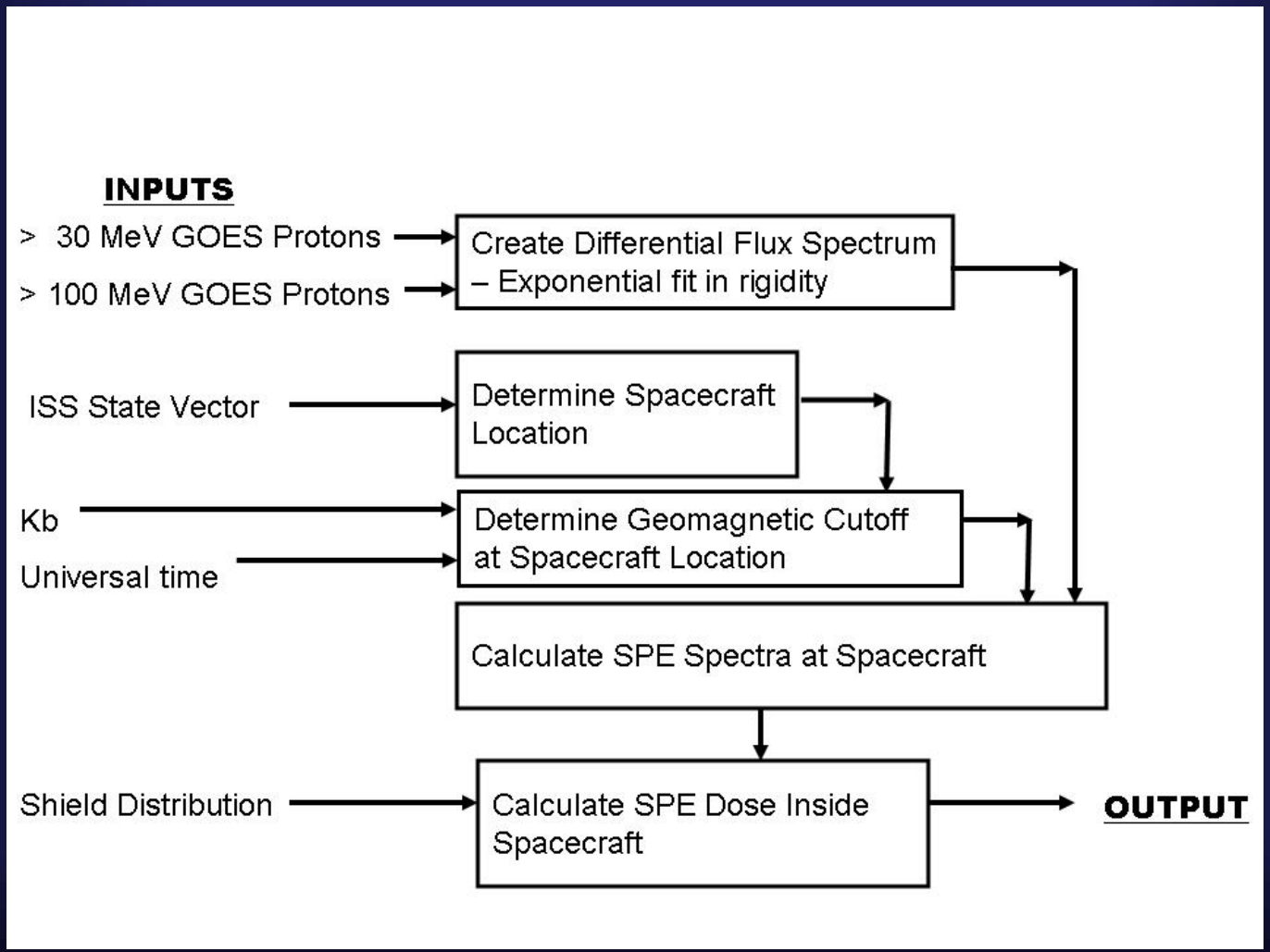
Always Check With Your Friendly

Neighborhood Space Weather Man

Extra Charts

P100 Mev Peak Value




INPUTS
> 30 MeV GOES Protons
> 100 MeV GOES Protons
Create Differential Flux Spectrum – Exponential fit in rigidity
ISS State Vector
Determine Spacecraft Location
Kb
Universal time
Determine Geomagnetic Cutoff at Spacecraft Location
Calculate SPE Spectra at Spacecraft
Shield Distribution
Calculate SPE Dose Inside Spacecraft
OUTPUT